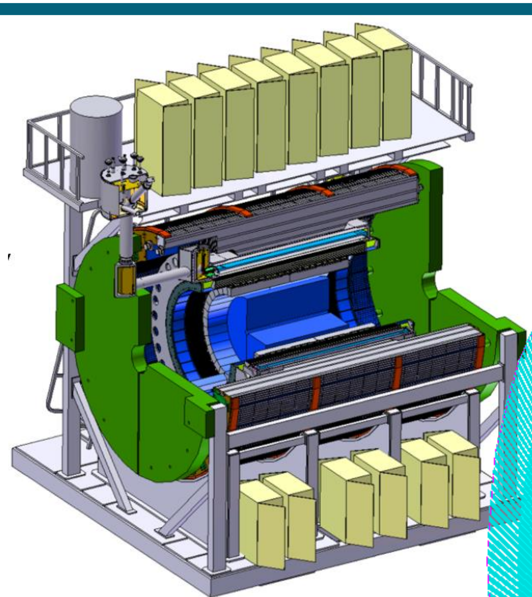
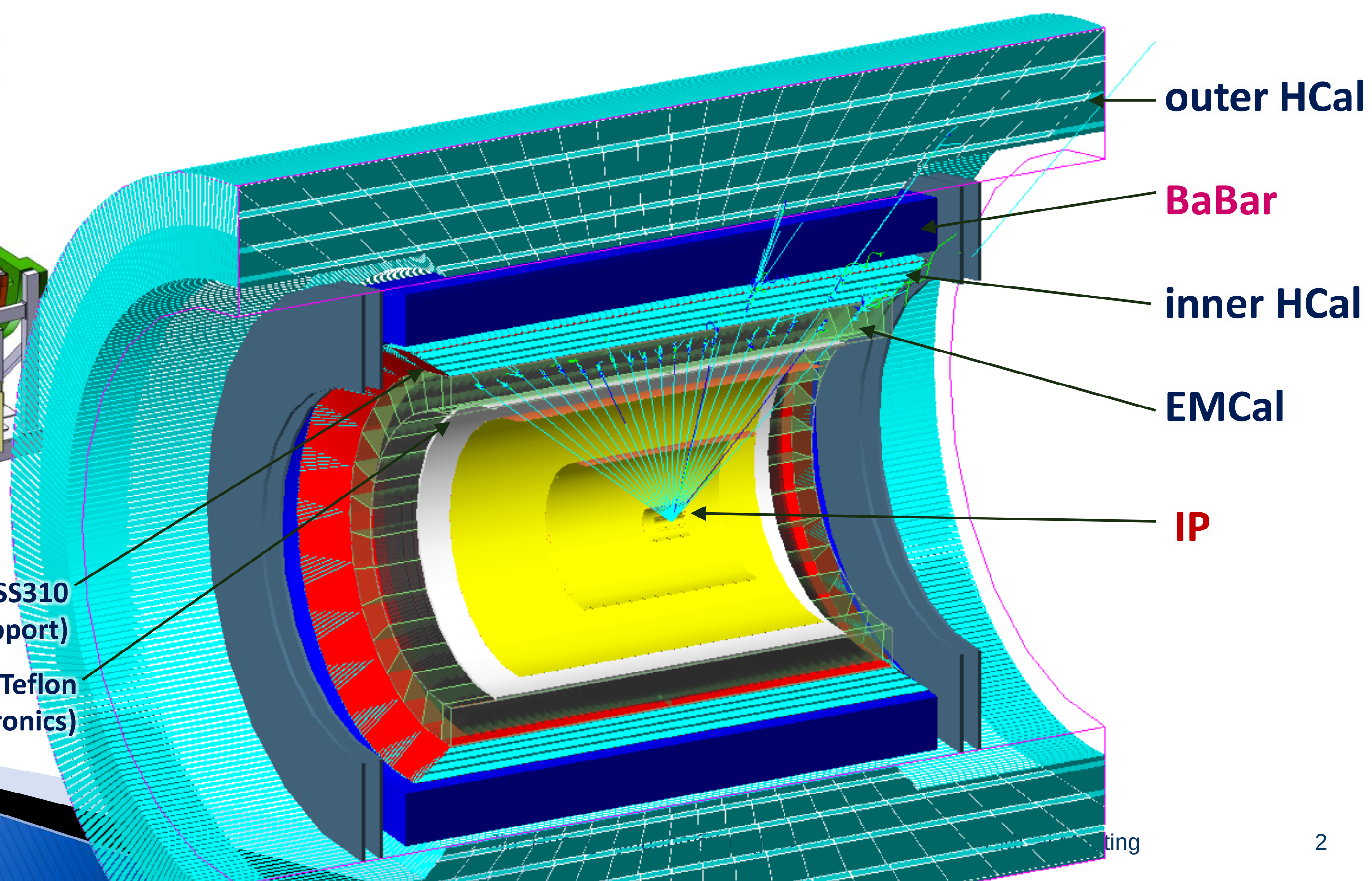
A few updates on simulations

Jin Huang (BNL)

sPHENIX Calorimeters in Geant4

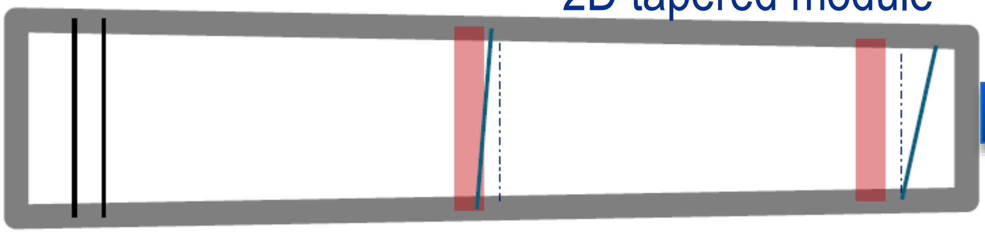
- EM calorimeter (EMCal) : 18 X_0 SPACAL
- Inner hadron calorimeter (inner HCal) : 1 λ_0 SS-Scint. sampling
- BaBar coil and cryostat. (BaBar): 1.4 X_0
- Outer hadron calorimeter (outer HCal) : 4 λ_0 SS-Scint. sampling

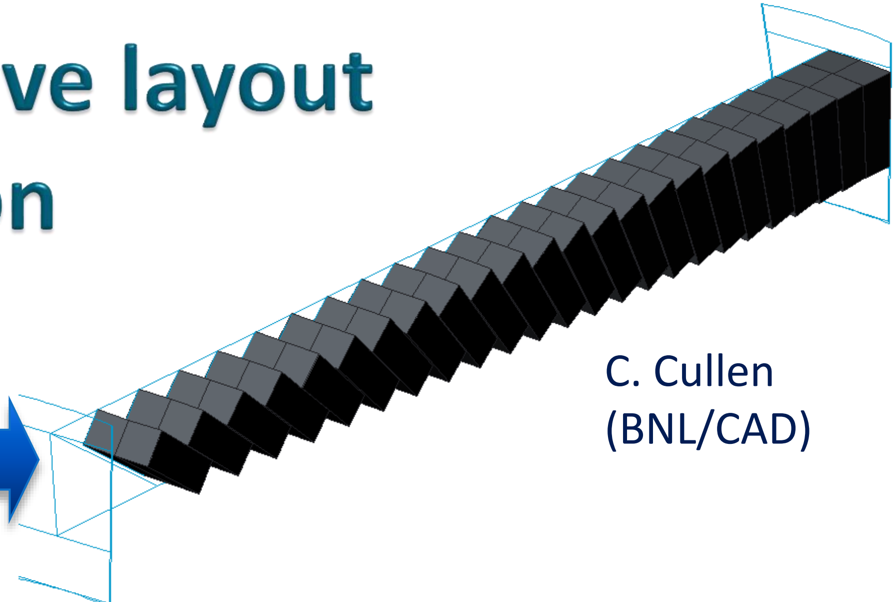




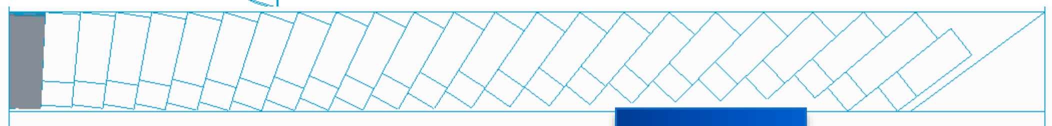
On-going: 2-D projective layout from CAD to simulation

2D tapered module



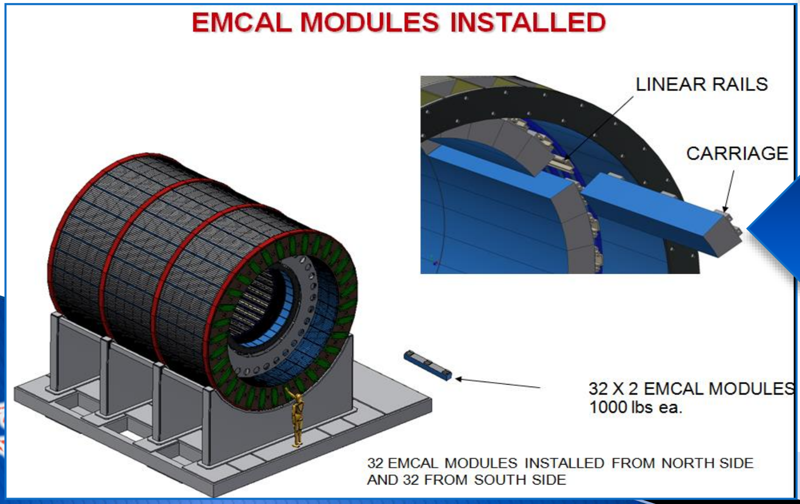


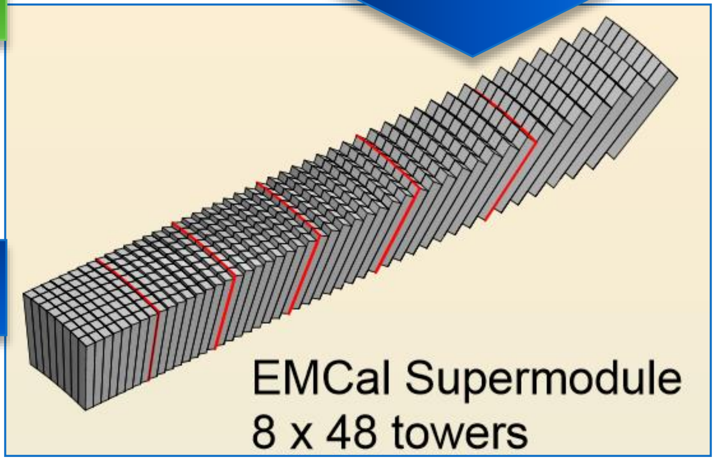
C. Cullen (BNL/CAD)



Simulation for 2-D projective EMCal: Plan to import the CAD geometry into sPHENIX Geant4

End July

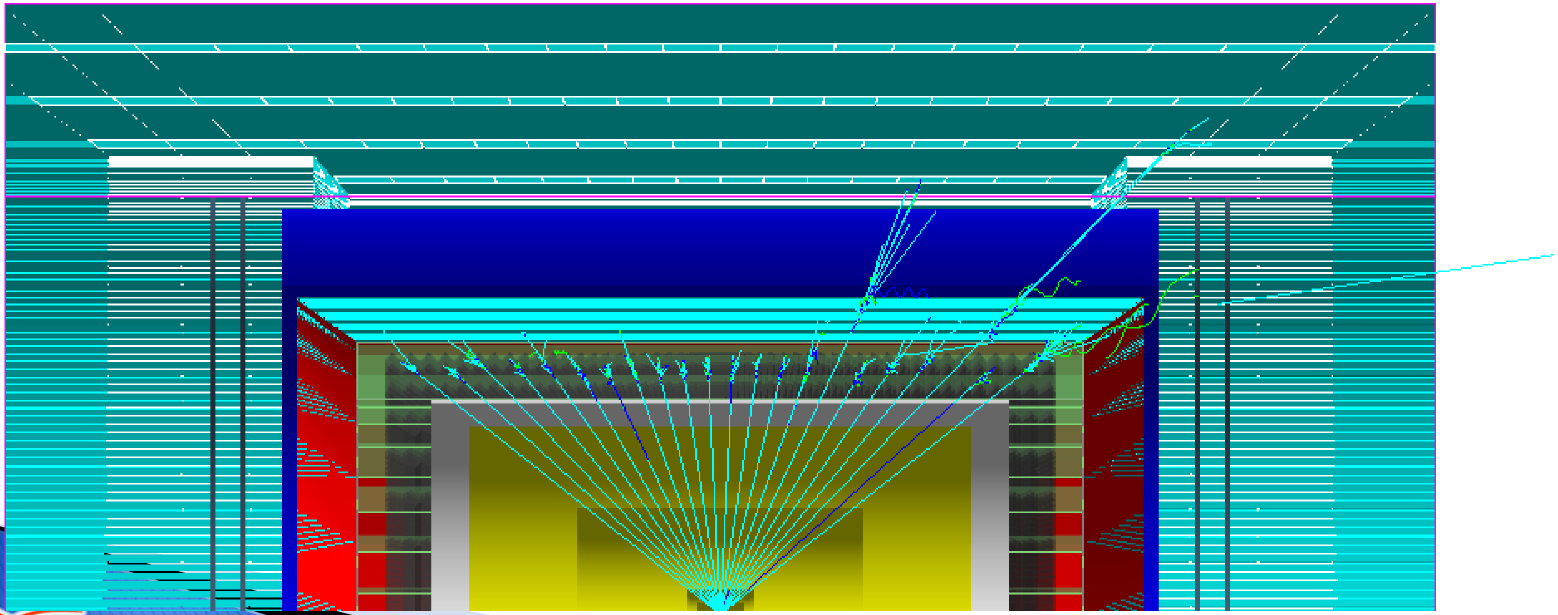


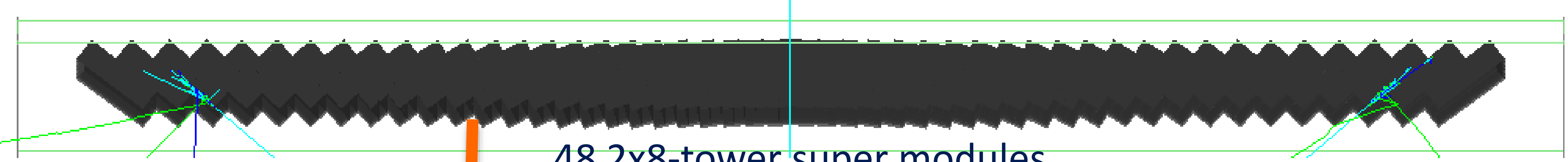


(Not yet updated to 2x2 block)

Implementation in Geant4

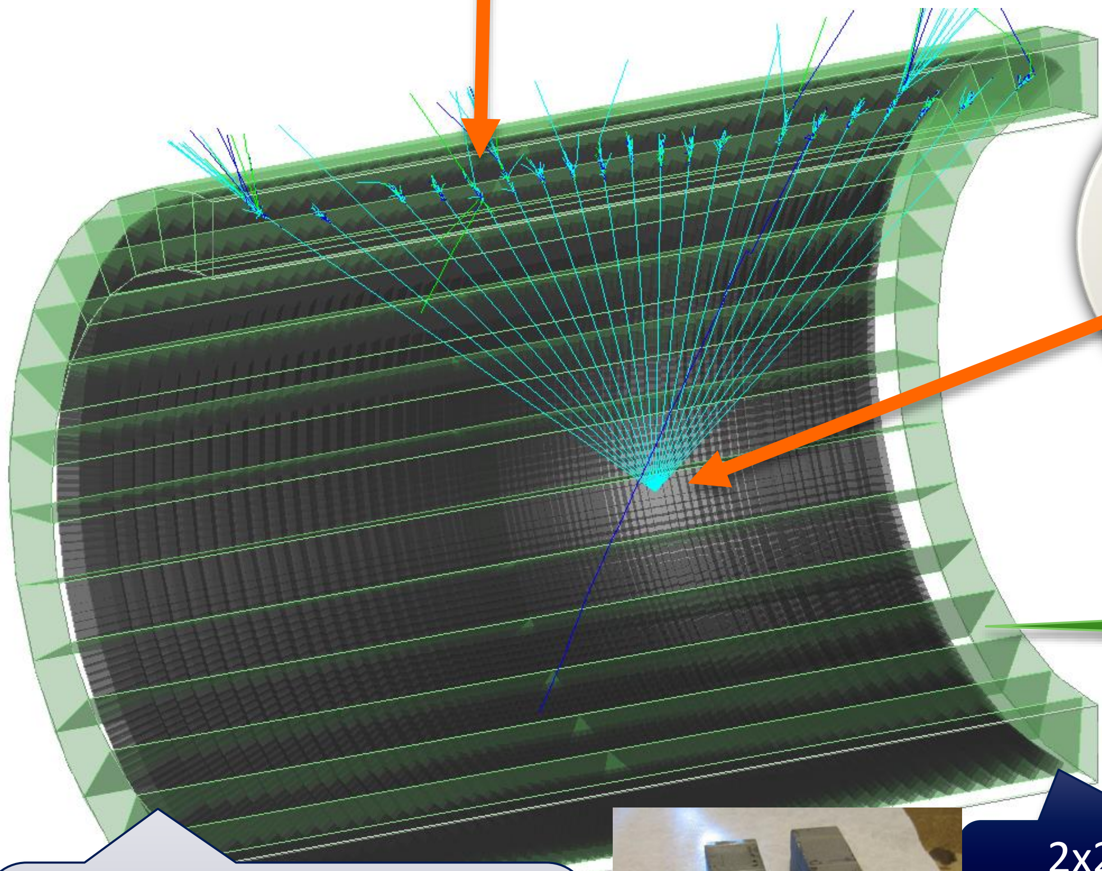
- Enabled with new branch 2DSpacal:
  - In nightly build, but not used by default
    - https://github.com/sPHENIX-Collaboration/macros/pull/2
    - https://github.com/sPHENIX-Collaboration/coresoftware/pull/19
  - Activated with this flag in Fun4All_sPHENIX.C
    `Cemc_spacal_configuration = PHG4CylinderGeom_Spacalv1::k2DProjectiveSpacal;`
- After many optimization, currently still need ~5min to run the first event due to large number of unique geometry objects. Then ~2 EM shower/min

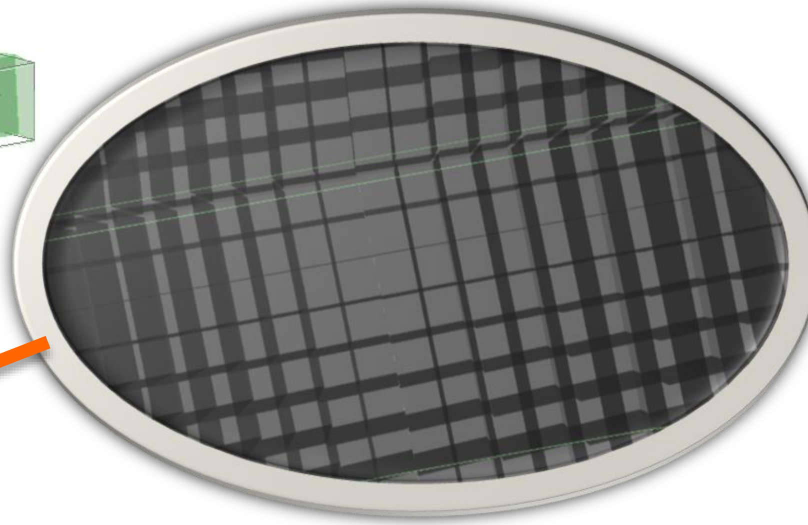




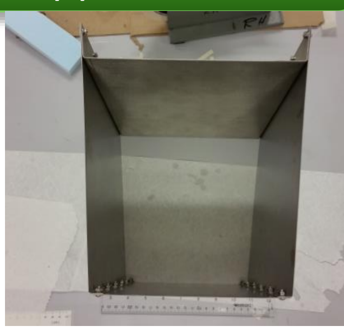
48 2x8-tower super modules

Towers project towards IP





Stainless steel SS310
Support box



2x2 2D tapered
SPACAL modules

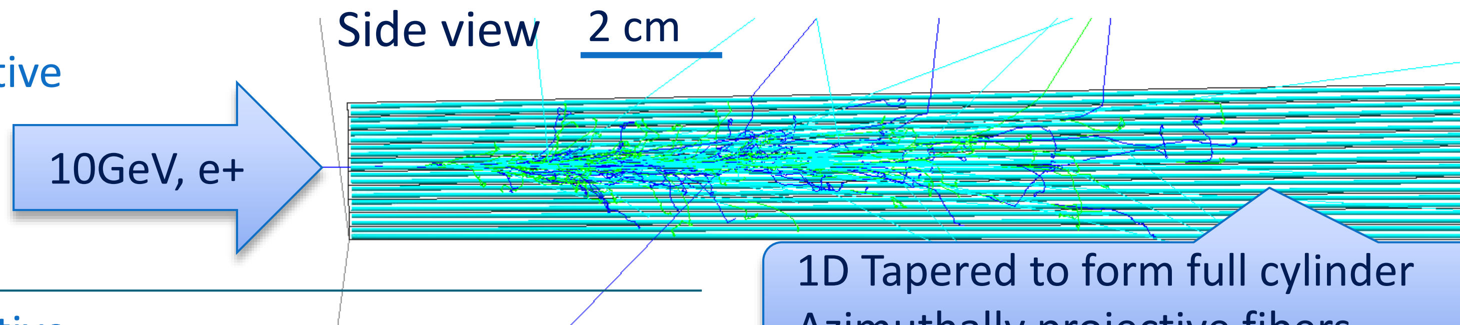
Gap between modules are also implemented

- 300um tolerance outside super modules skins
- ~2mil between SPACAL and SS skin
- ~2mil between SPACAL modules

Detail view – Fiber display

- Tungsten + Epoxy material: 12.18 * g / cm3, 96.9% mass with W
- Fiber: ϕ440um core (Polystyrene) + 15um skin (PMMA)
  - Thanks to the reference model from A. Kiselev (EIC taskforce & EIC RD1)
- Fiber matrix is layout in triangle pattern with a nominal separation of 1mm. Fiber at least 100um away from surface
- Default: 1-D projective in azimuth. New also available for test: full projective module

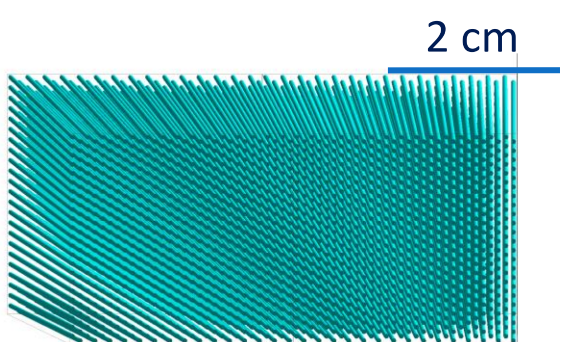
1-D projective



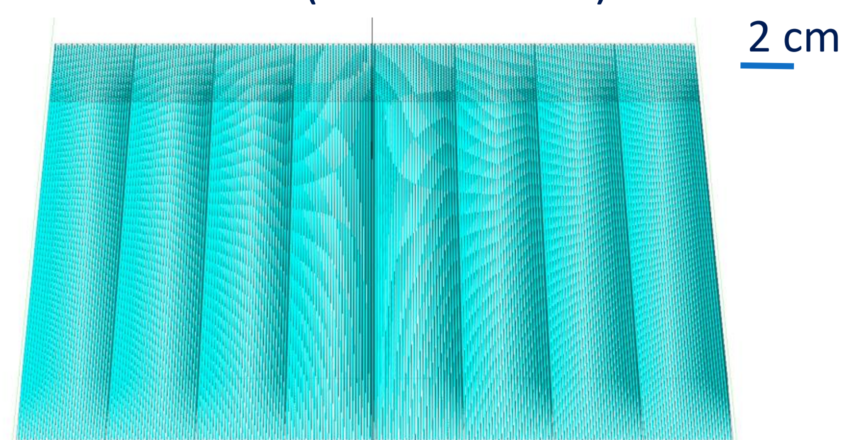
1D Tapered to form full cylinder
Azimuthally projective fibers

Full projective

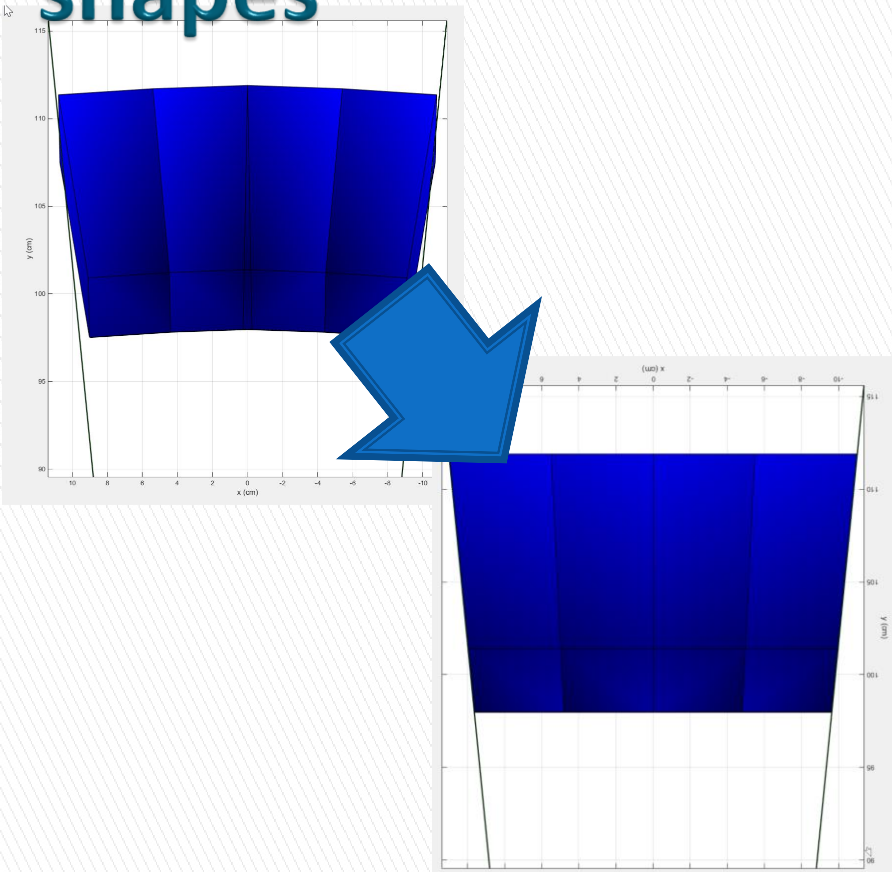
Particle view (2x1 modules)

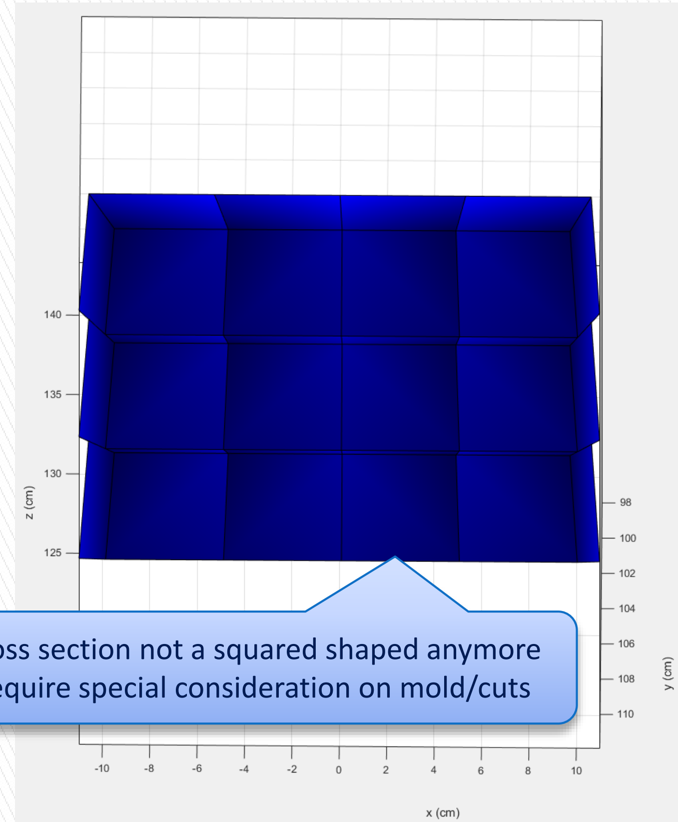


Side view (8x1 modules)



Detail view – adjustment of tower shapes





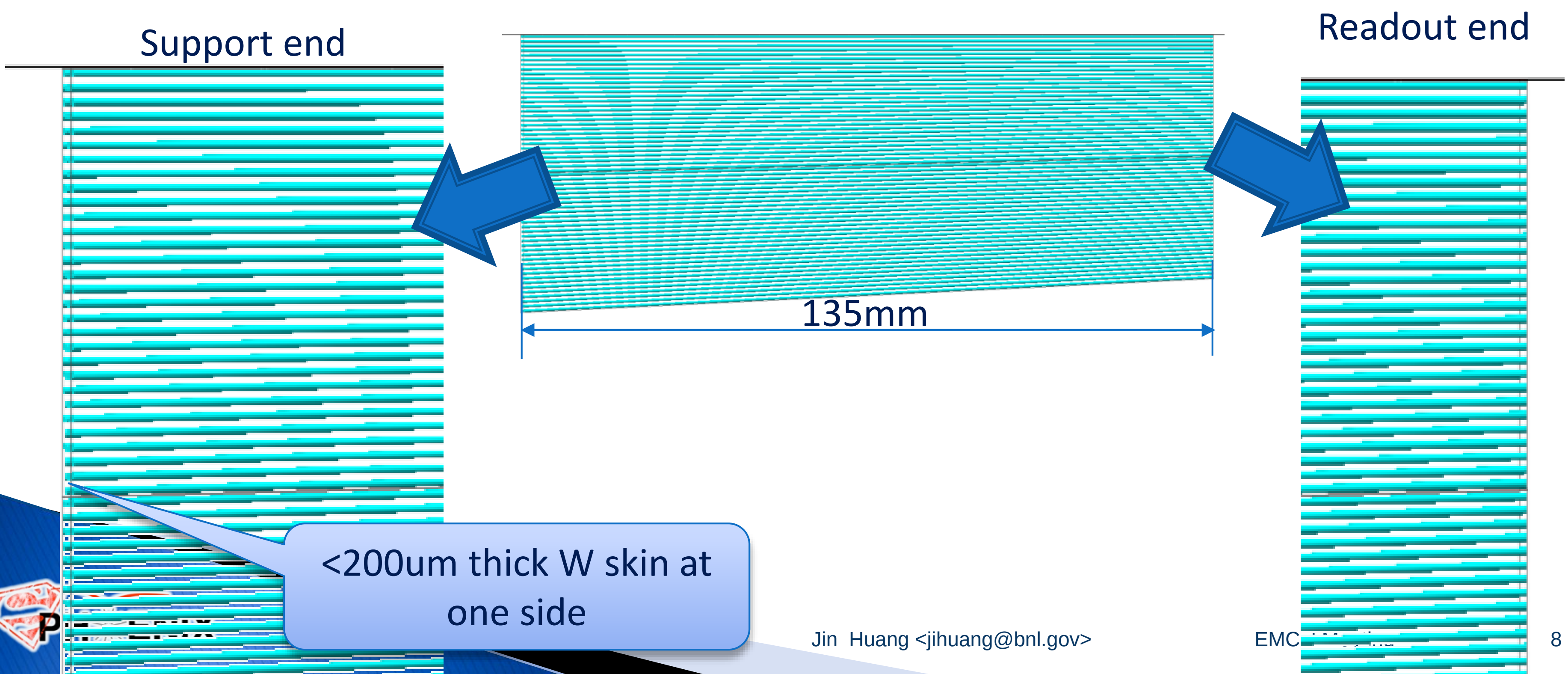
Cross section not a squared shaped anymore
Require special consideration on mold/cuts

View from end

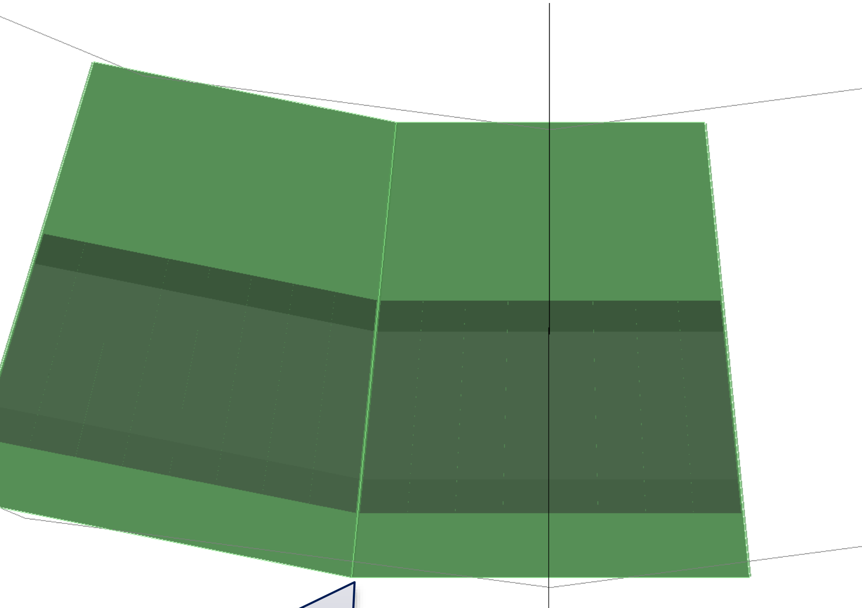
View from beam

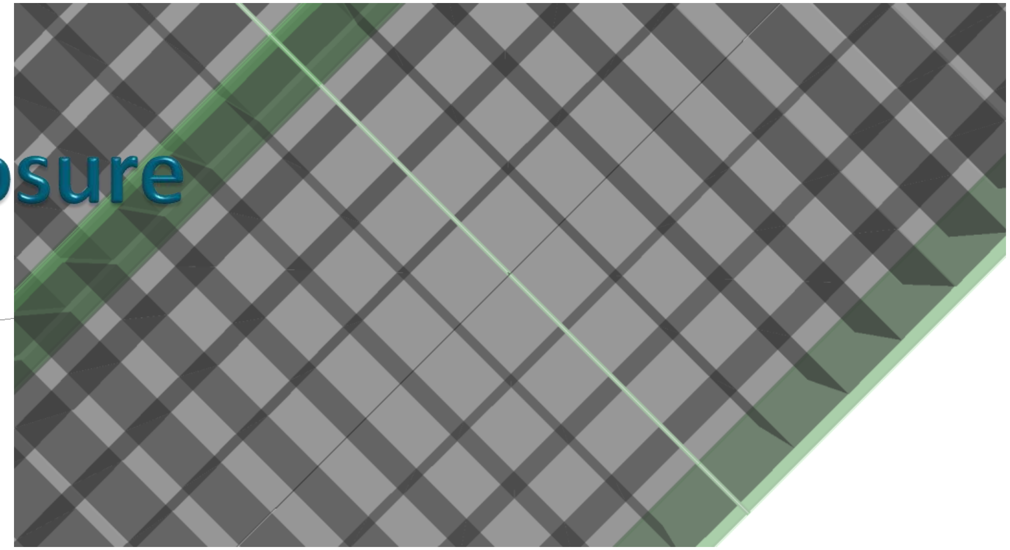
Detail view –
One trick used to speed up construction

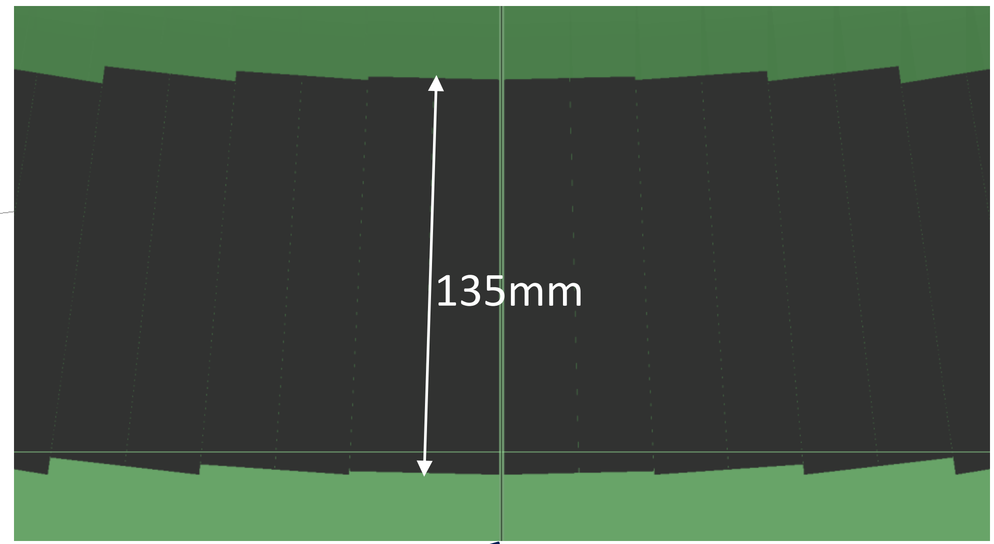
- Most fibers (~700/module) has different length in each SPACAL module (~400 unique pieces), which leads to large number of logical volume in G4, which take ~5min to construct
- Tremendously speed up by using same fiber length per module. This leave a <200um thick W skin at the end of the modules. Expect negligible impact to simulation precision.



Detail view – super module enclosure



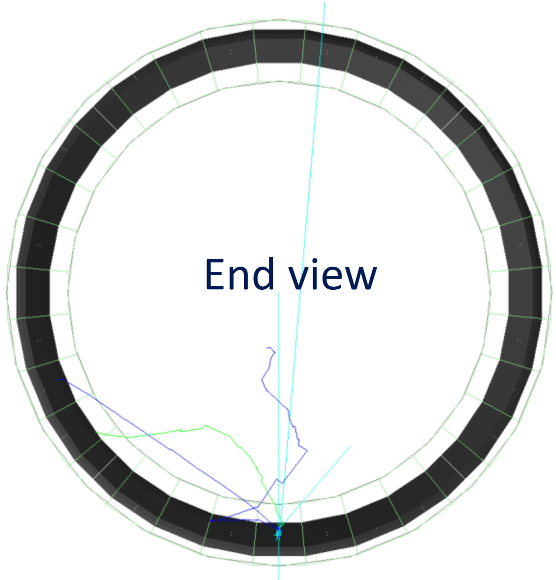


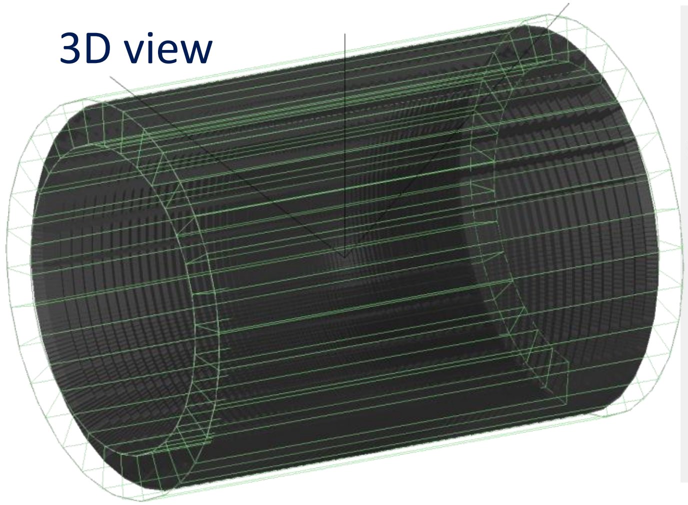


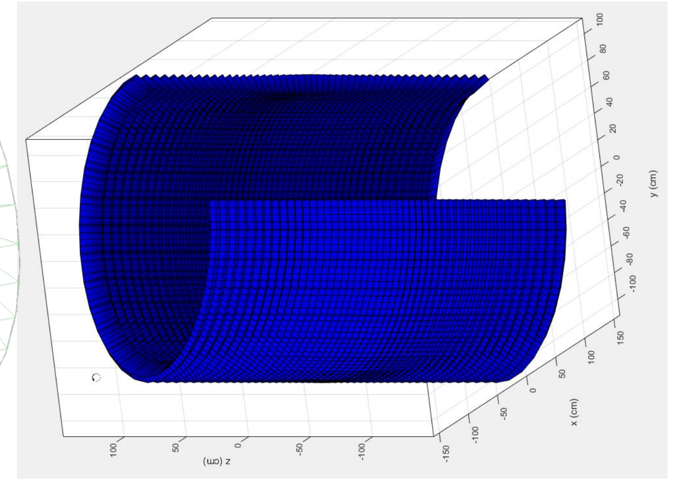
Side walls:
750um SS310 steel skin
300um tolerance outside super modules skins (gap thickness = 600um)

end walls:
750um SS310 steel skin
2mil tolerance outside super modules skins (gap thickness = 50um)

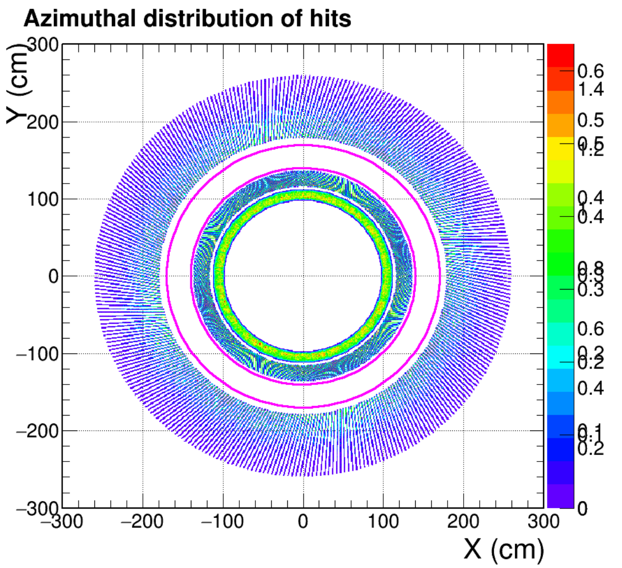
Detail view – more view

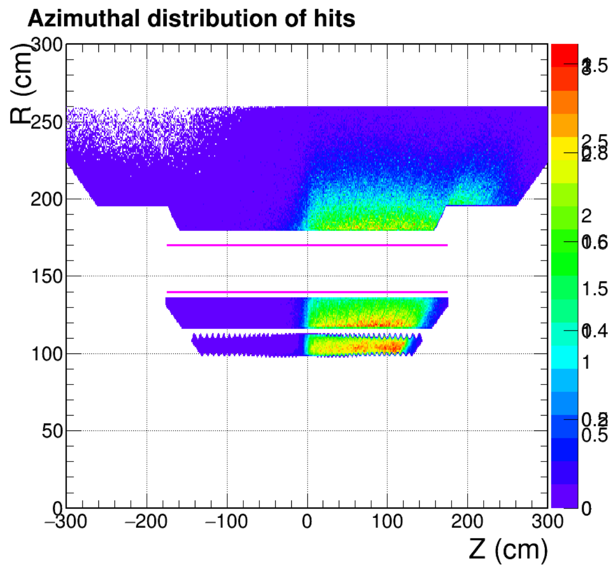




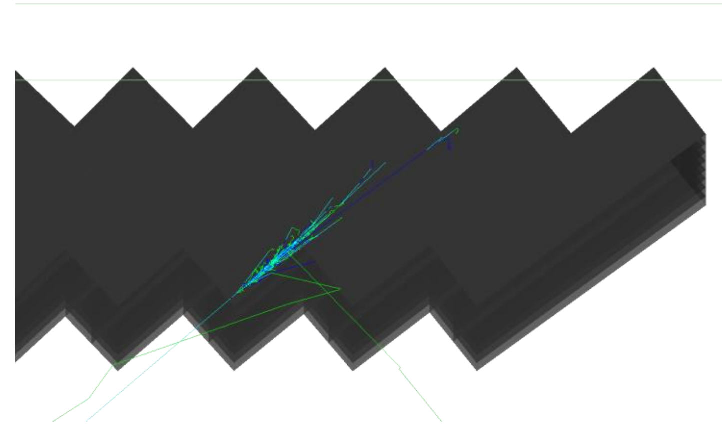


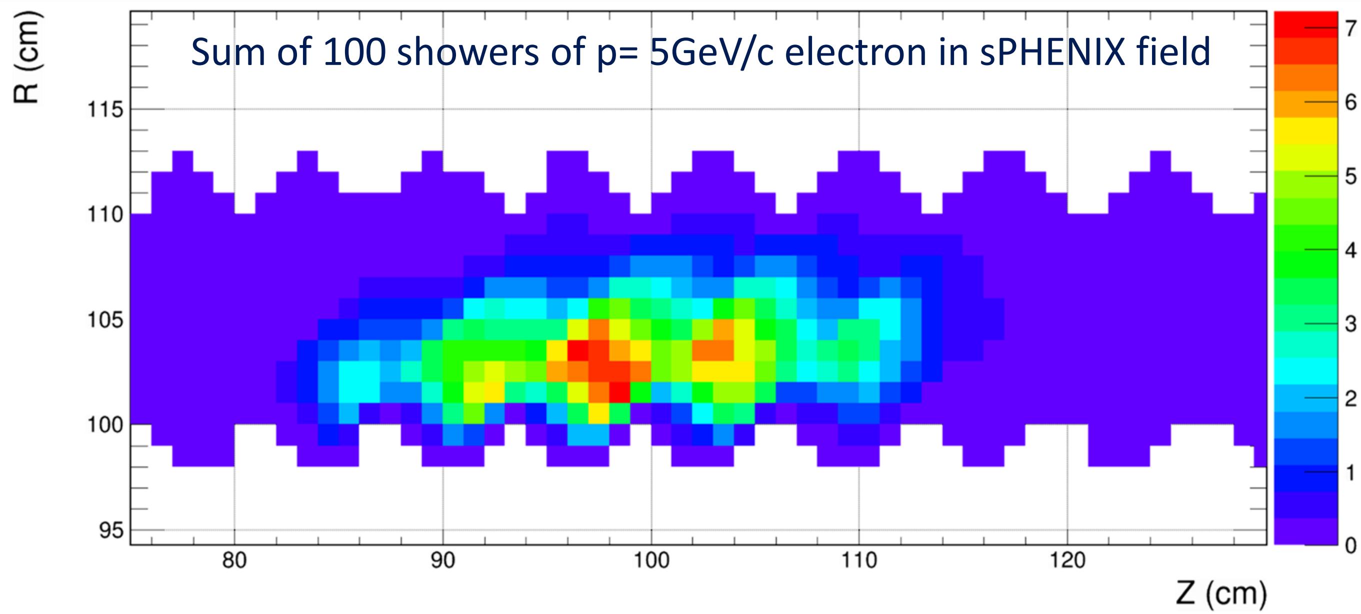
p_T = 4GeV/c negatively charged pions

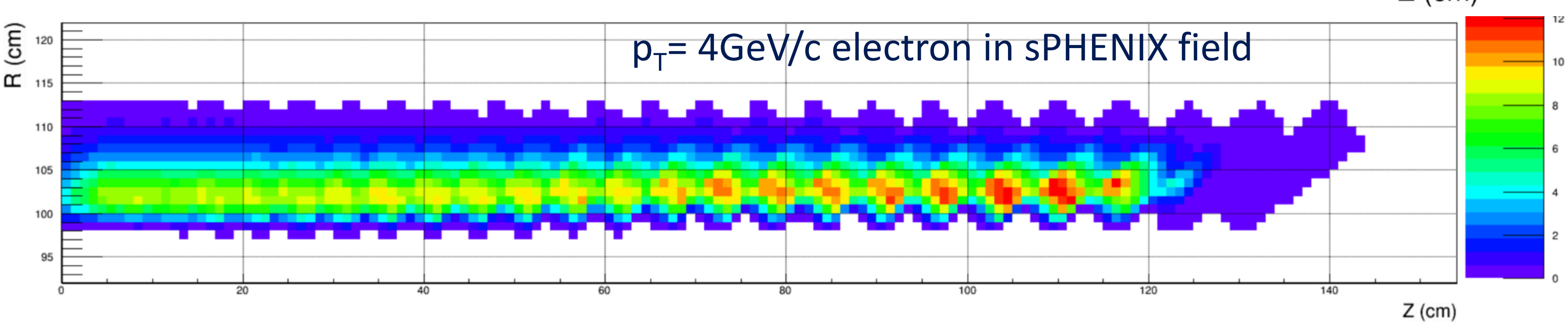




Energy distribution



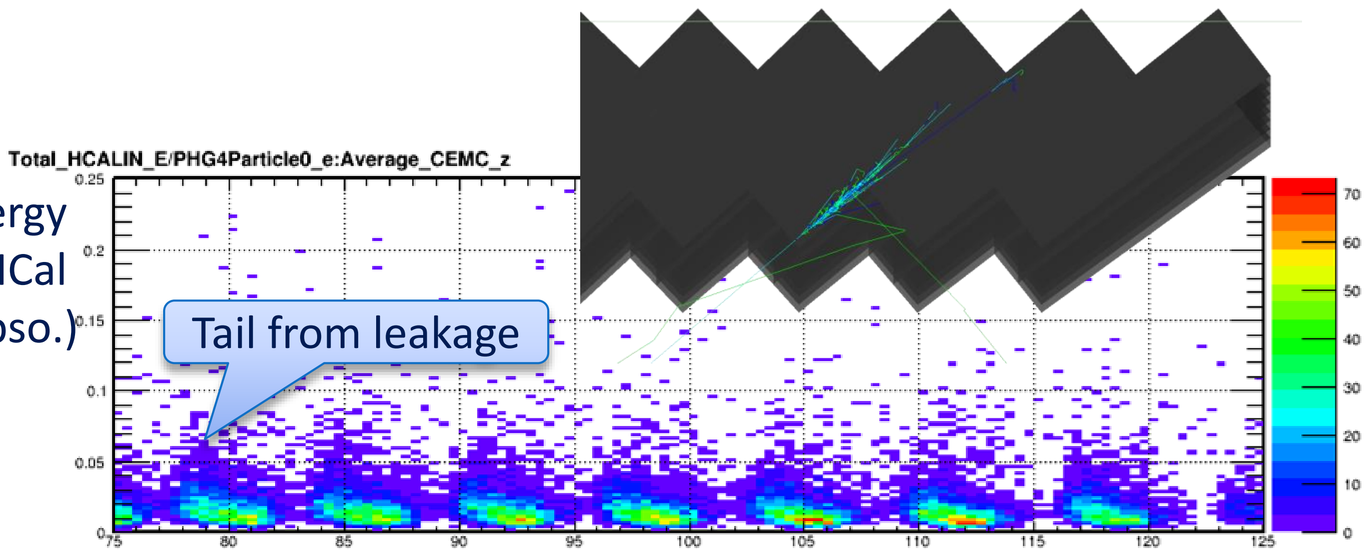




Leakage looks OK so far (vs <z>). Still in verification

p_T= 4GeV/c electron in sPHENIX field

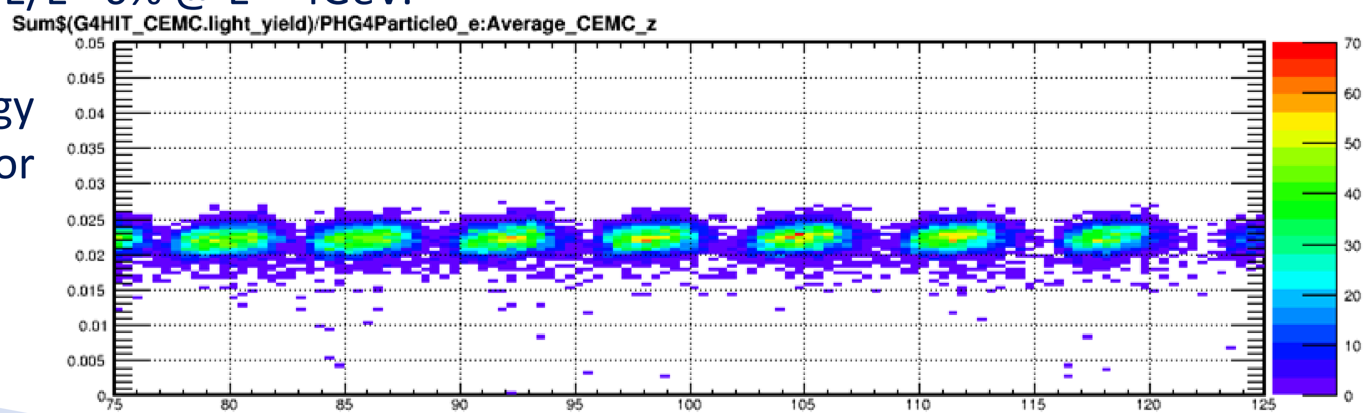
Ratio of energy in inner HCal (scint + abso.)



<z> of each shower in cm

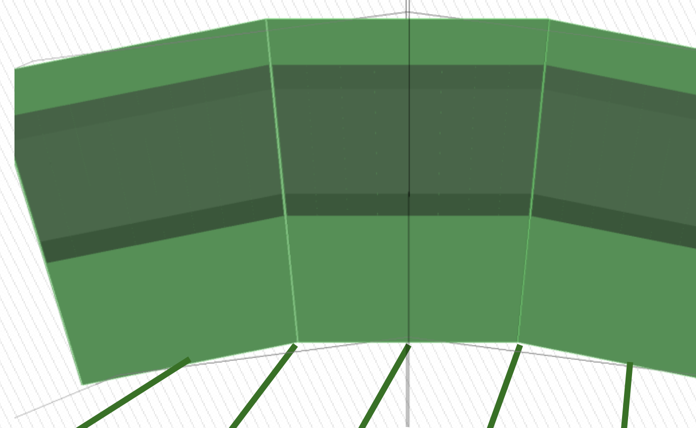
In comparison to energy resolution dE/E~ 6% @ E = 4GeV:

Ratio of energy in SPACAL scintillator



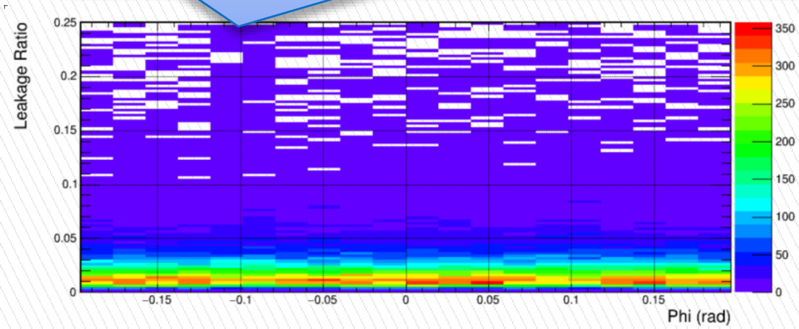
<z> of each shower in cm

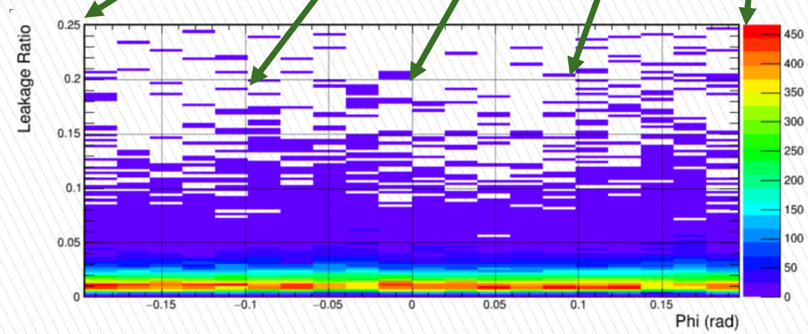
Azimuthal Leakage also not so bad
p_T= 4GeV/c particles in sPHENIX field
-5 cm < vz < 10 cm, 0<eta<1.0



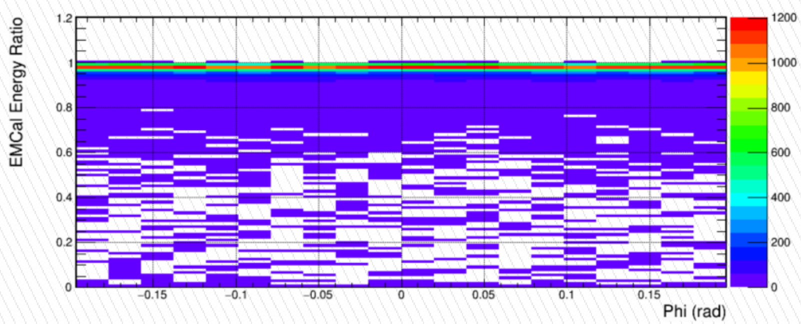
Super module edge:
600um gap over 20cm length
or ~0.3% azimuthal gap
acceptable effect: negligible (?) lower photon eff.

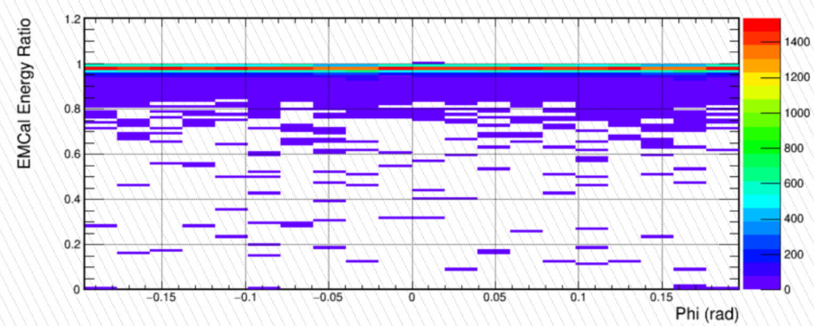
Ratio of energy in inner HCal (scint + abso.)





Ratio of energy in SPACAL (scint + abso.)



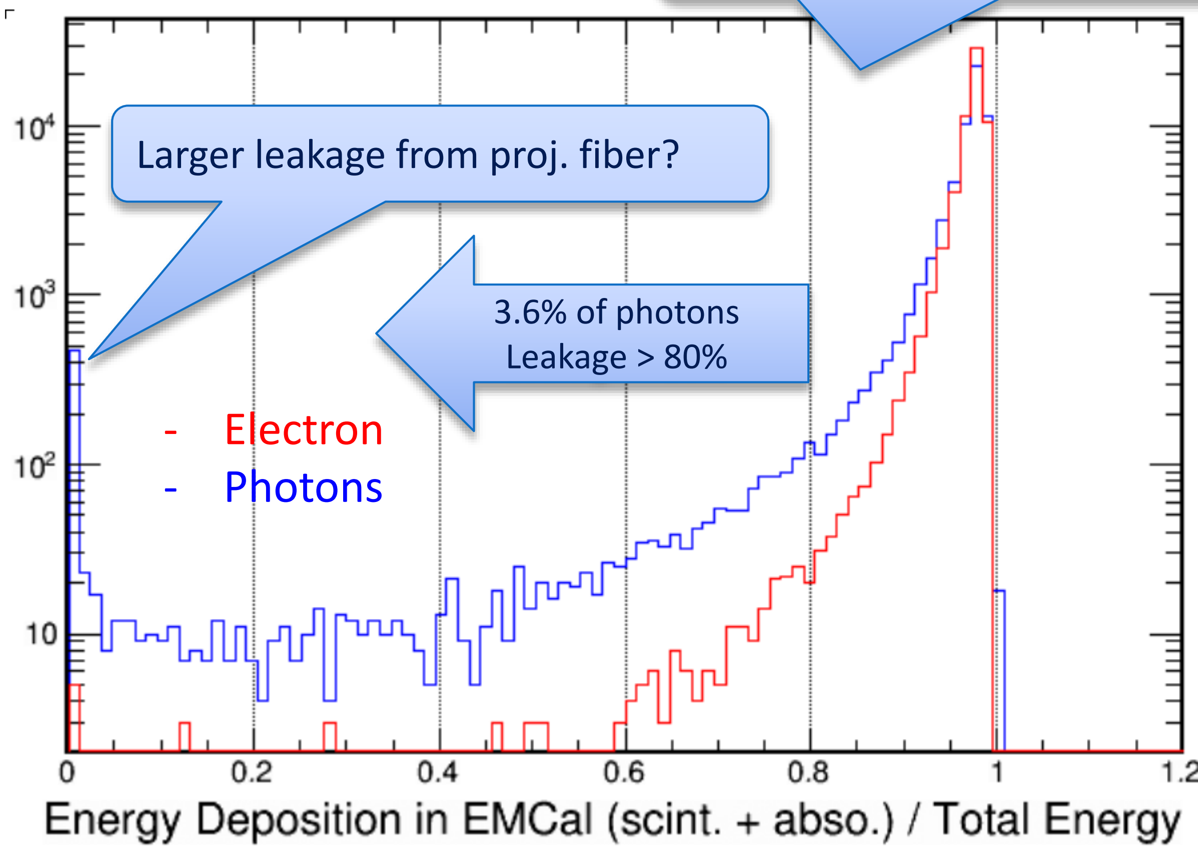


Photons

Electrons

Leakage: integrated over acceptance
p_T= 4GeV/c particles in sPHENIX field
-5 cm < vz < 10 cm, 0<eta<1

8% of photon leave 80-90% energy in EMCal
-> kinematic smearing in gamma-Jet measurements



Do we have that with realistic waving fiber?
Solution: Tilt SPACAL by 25 mrad? Inner HCal veto?

On-going works

- I am verifying the 2D projective setup and revise the performance plots
- Eliton Seidel (Baruch College) is verifying the parameters for Geant4 to model showers in SPACAL
- Nils Feege (SBU) is testing machine learning tools (boosted decision tree and support vector machine) on analyzing EMCal + innerHCal data.

Path forward

Geant4 Implementation

- In nightly built
- (G4 default) Birk effect applied
- Need larger production sample
- Need to finish fine tune and verification of Geant4 parameters
  -- Studies --
- Quantify leakage & cracks
- Variation of sampling fraction

Digitalization

- Need some details in mapping hit to tower
- Add electronics noise
  -- Studies --
- Energy resolution
- Verify pion response VS test beam
- Uniformity VS edge/center of block/Super module, VS rapidity

Track – tower matching

- For charged tracks : extrapolate track to towers (need to tune the existing code)
- Clusterizer for photons (need new one for HI environment)
  -- Studies --
- Electron ID performance with EMCal towers + inner HCal
- Photon response
- Calibration

Final Projection

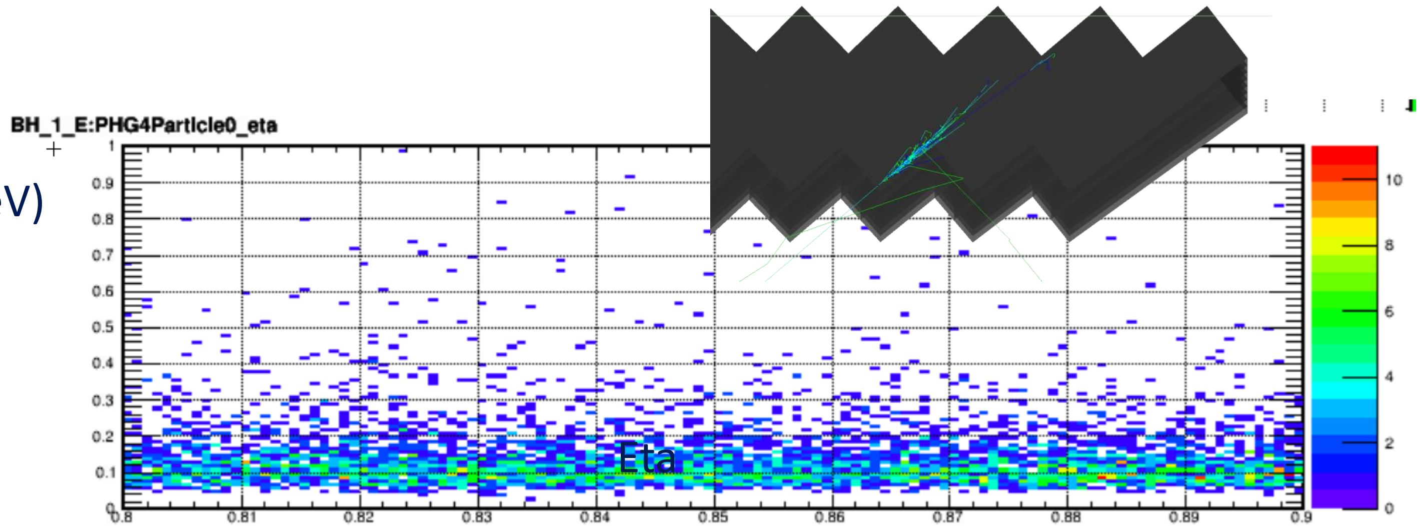
- Need Upsilon and background simulation
- Photon Jet samples
  -- Studies --
- Final di-electron candidate line shape near Upsilon peaks
- RAA projection
- Bin migration and unfolding for photons-jets

Extra Information

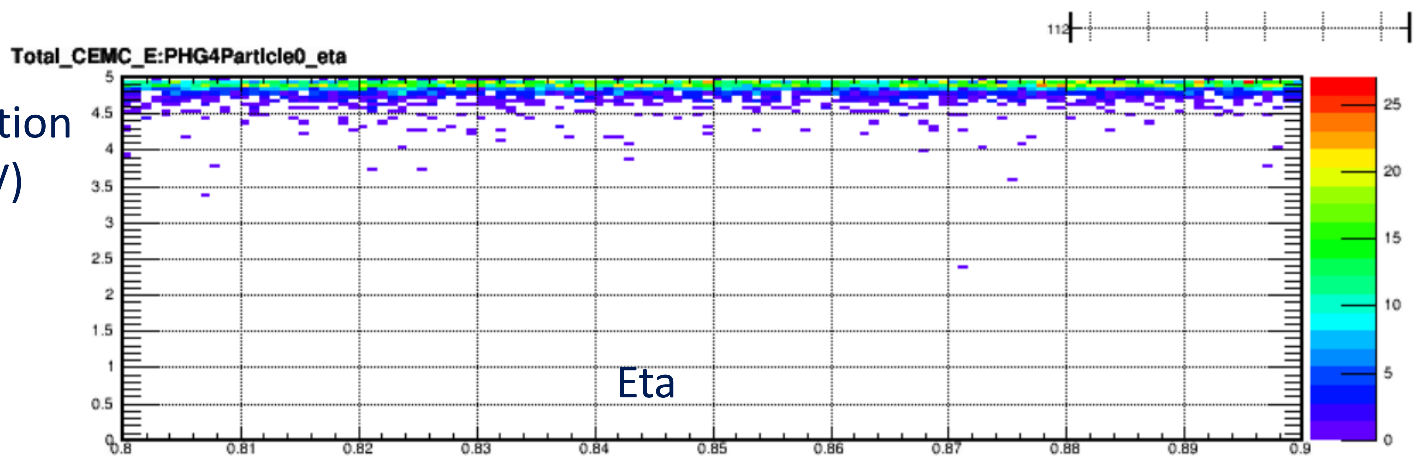
Looks smooth so far (vs eta). Still in verification

p= 5GeV/c electron in sPHENIX field

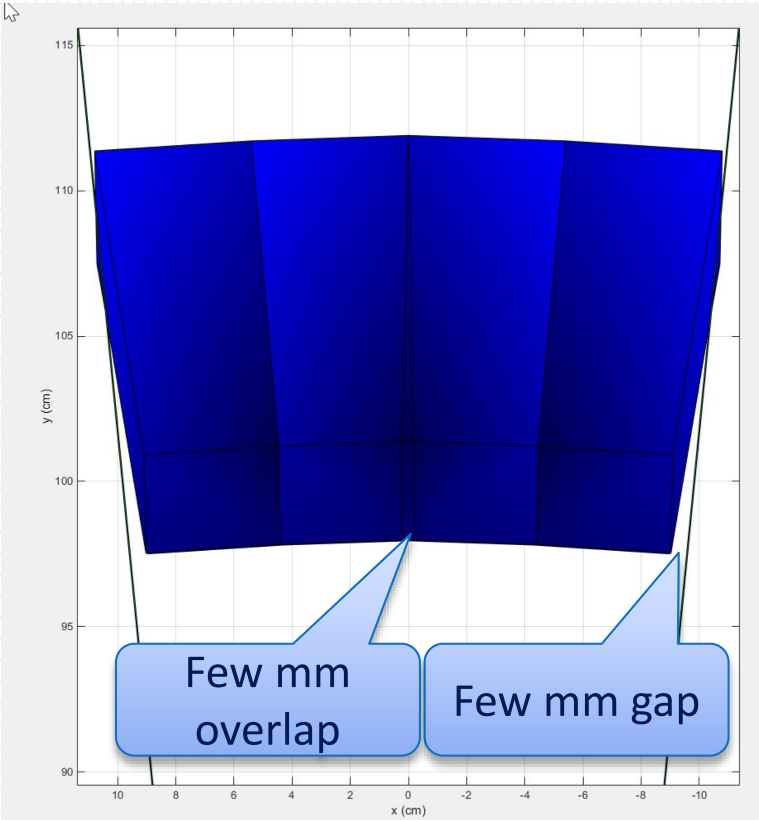
Leakage (GeV)



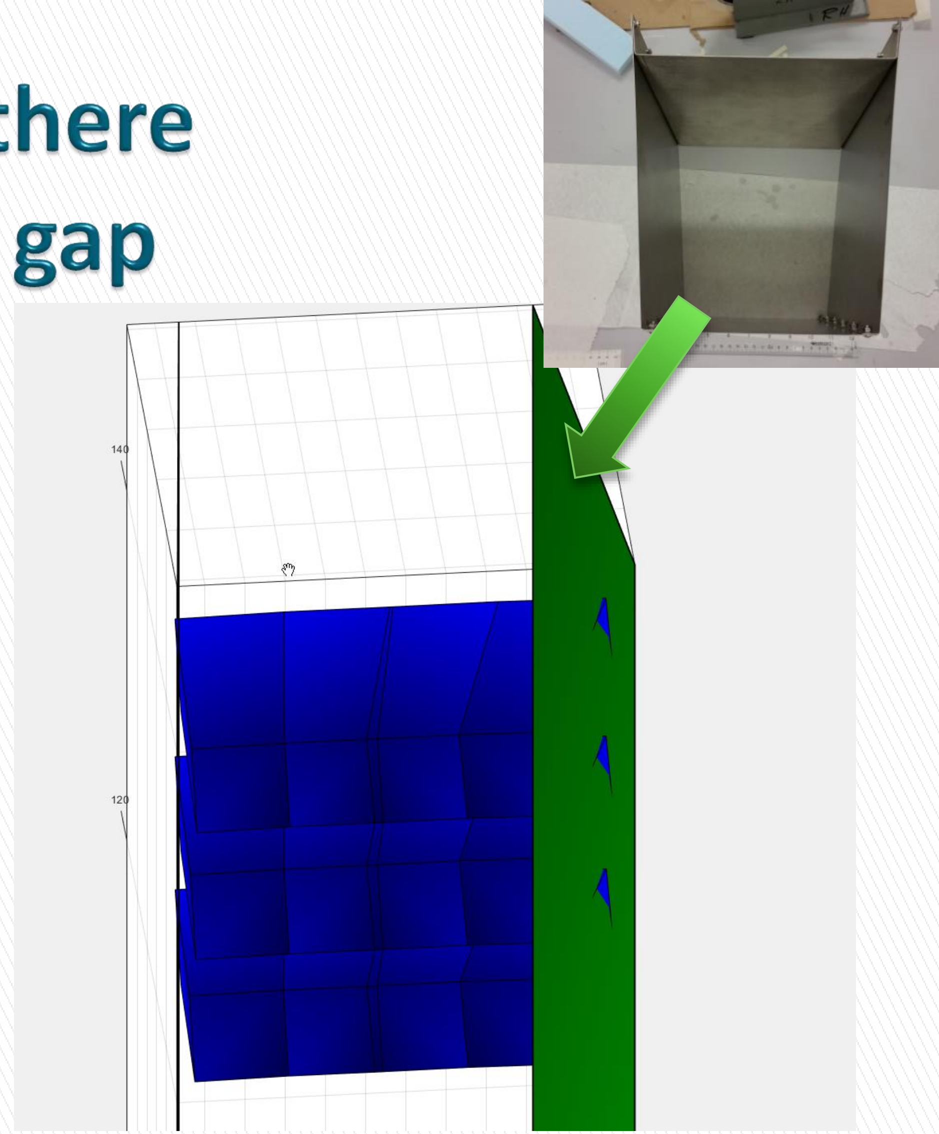
Energy deposition in SPACAL(GeV)



However, right now there is a confliction and a gap

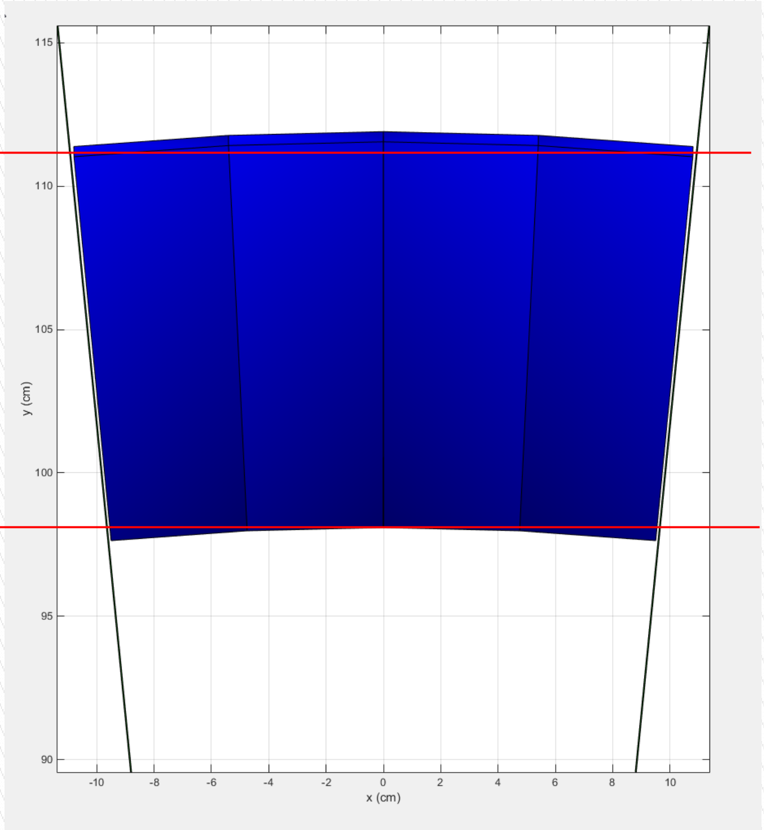


View of the last row of calorimeter long z axis

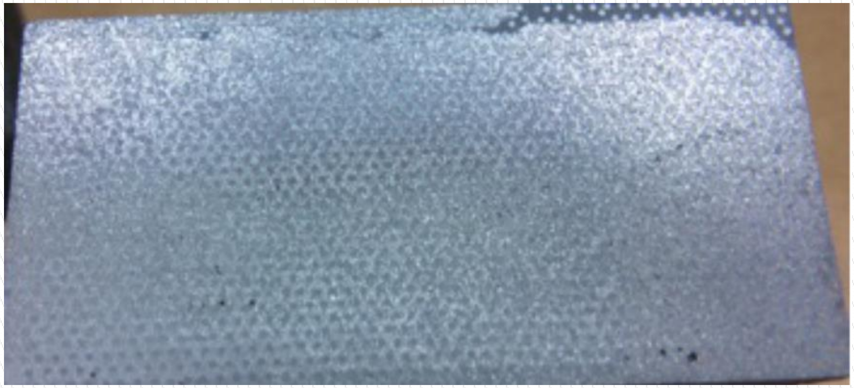


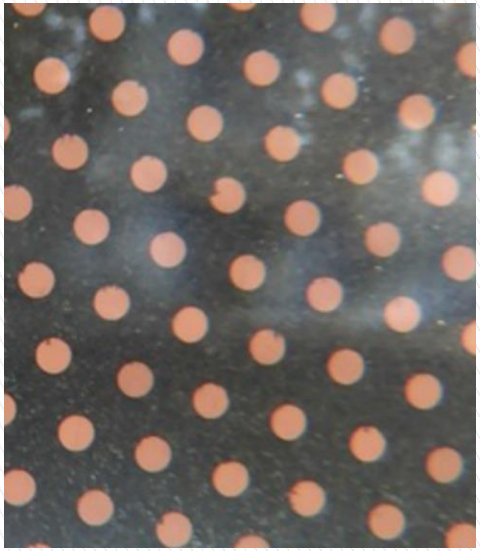
View of the last 3 rows of calorimeter from beam side

A solution



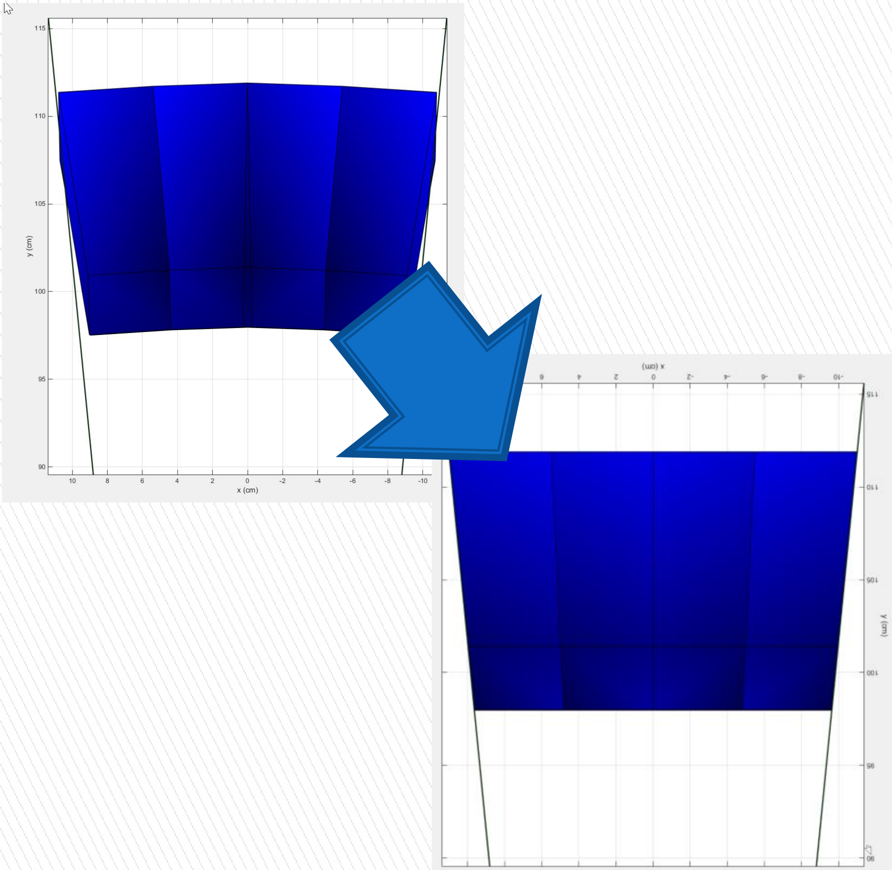
Build blocks to fit and machine cut top and bottom to flat

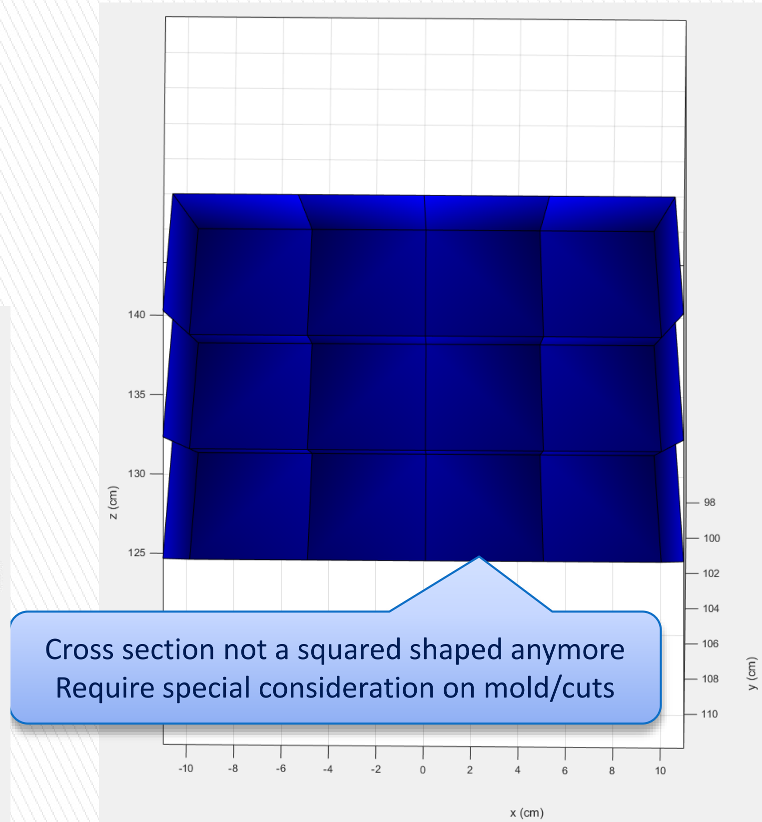




Experimental diamond cut UIUC group

Last row after the surface cut



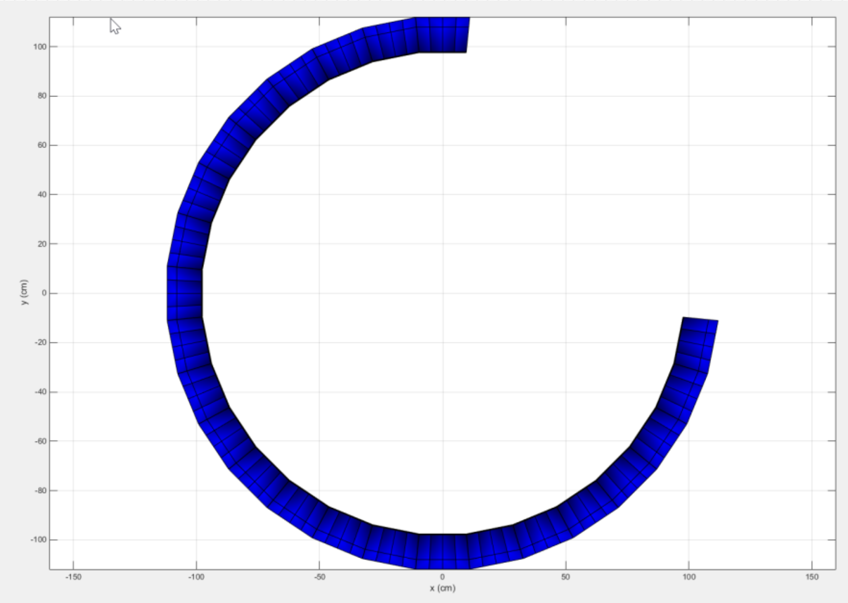


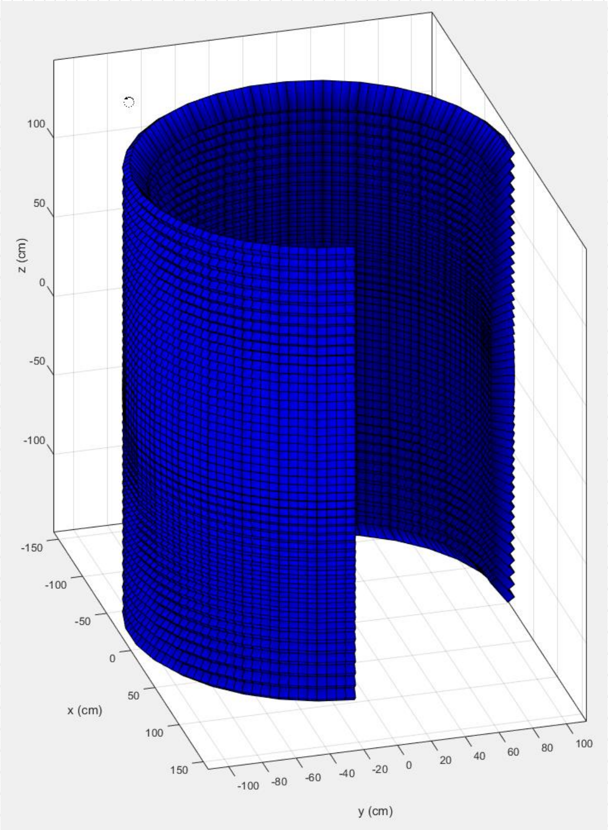
View from end

View from beam

Put it all together

- 2D R-Z layout from Chris
- Regenerated in MatLab
- now ready to export into Geant4





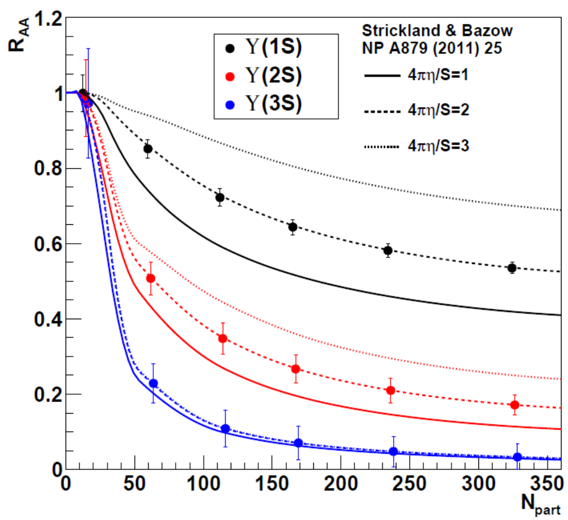
Beam-axis view

3D view

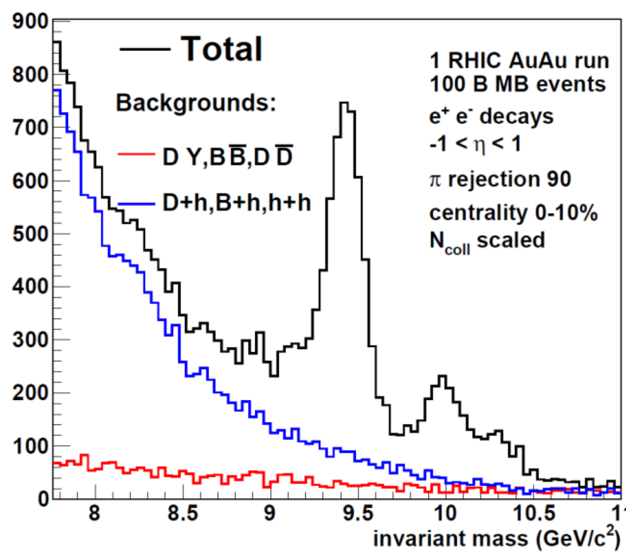
sPHENIX EMCal

1. Upsilon electron ID – main driving factor
2. Direct photon ID
3. Heavy flavor electron ID
4. Part of jet energy determination

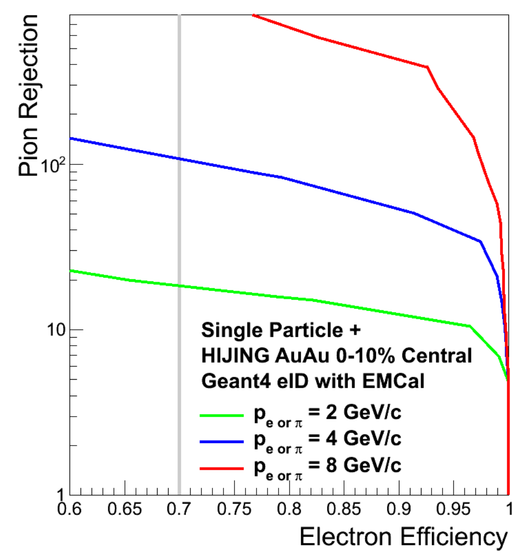
Upsilon R_{AA}



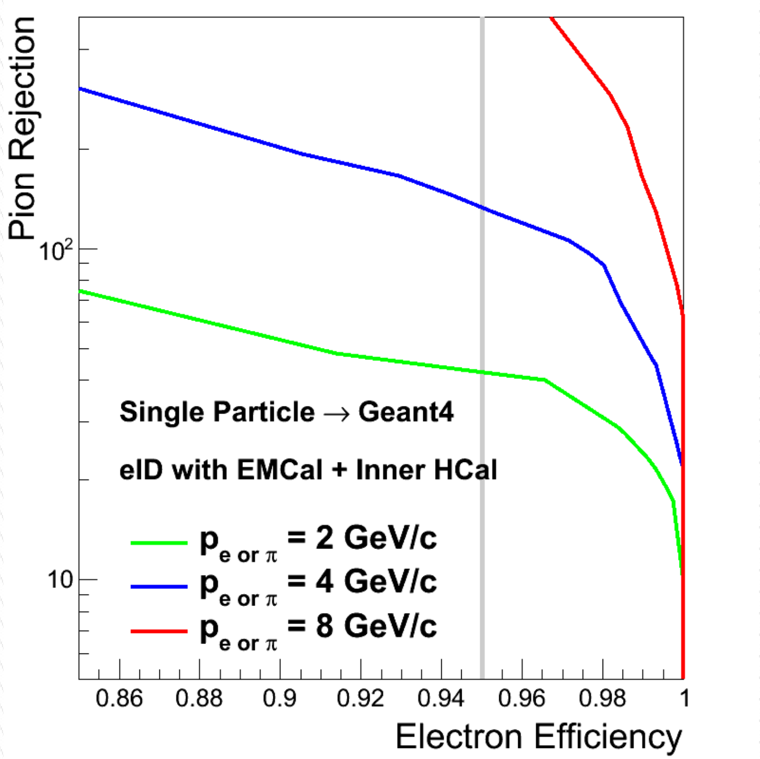
Hadron VS Upsilon



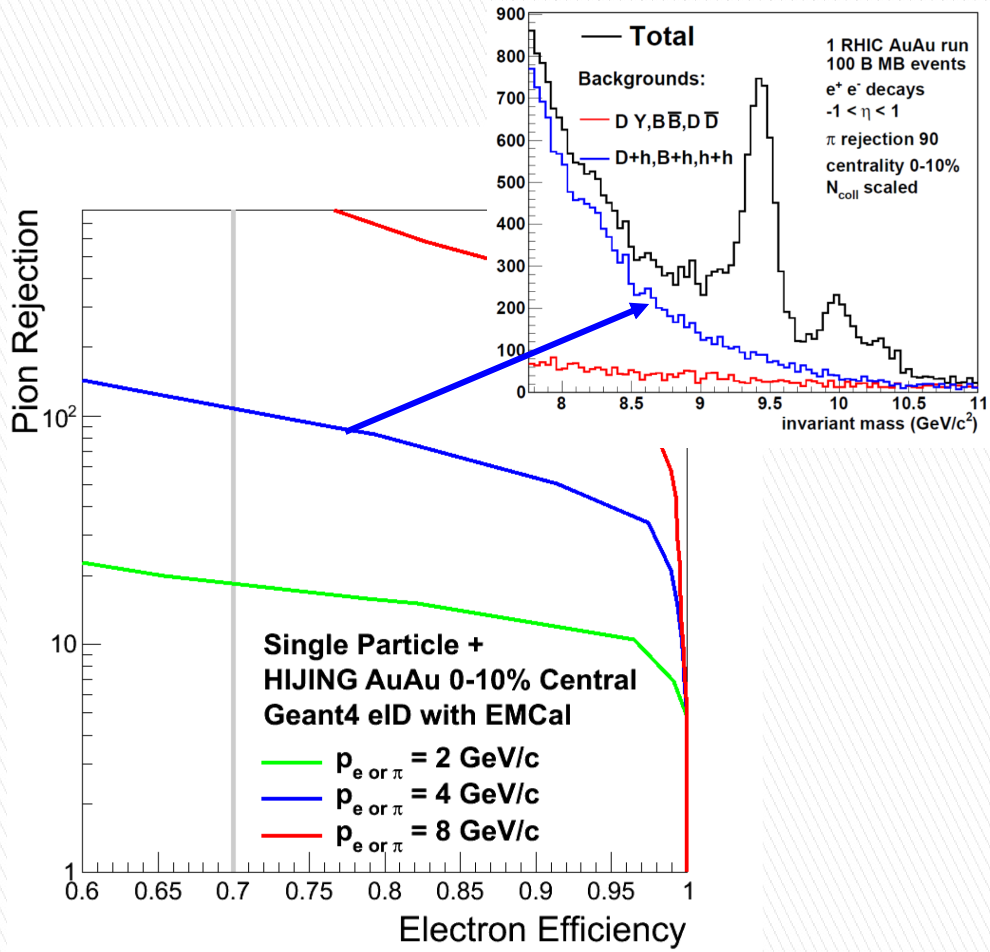
Hadron Rej. ~100:1



Compile everything together for barrel electron ID



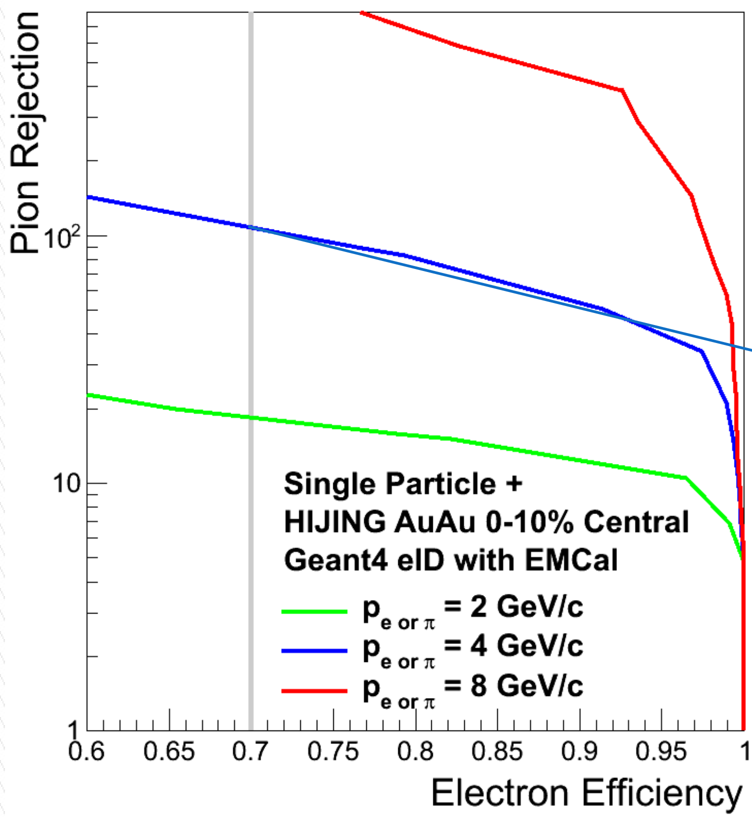
pp/ep electron ID (EMC+HCAL)

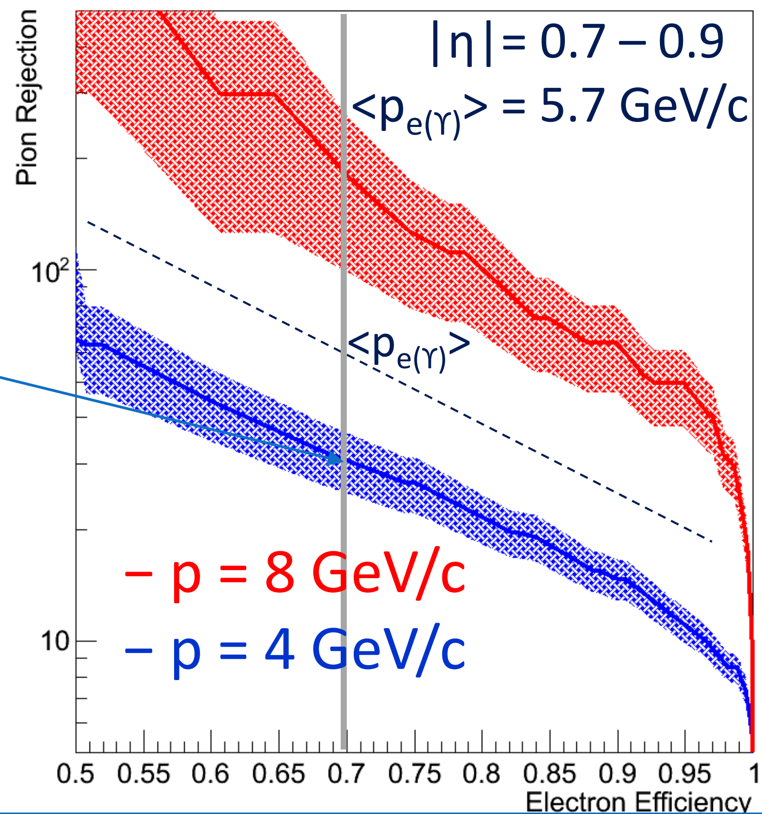


Central AA electron ID (EMC Only)

Fast group of Geant4 hit, need to re-evaluate in realistic towering!

Quantitative comparison for EID performance in Geant4 (group hits to simulate for towers)





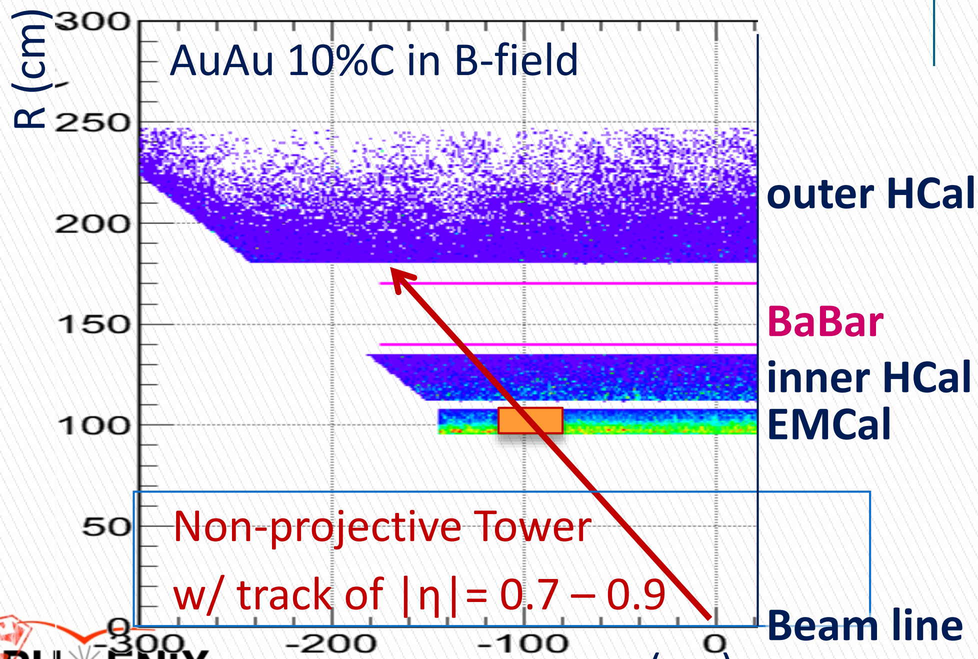
Central rapidity, |η|< 0.2
Effectively projective in polar direction

Forward rapidity, |η|= 0.7 – 0.9
non-projective in polar direction

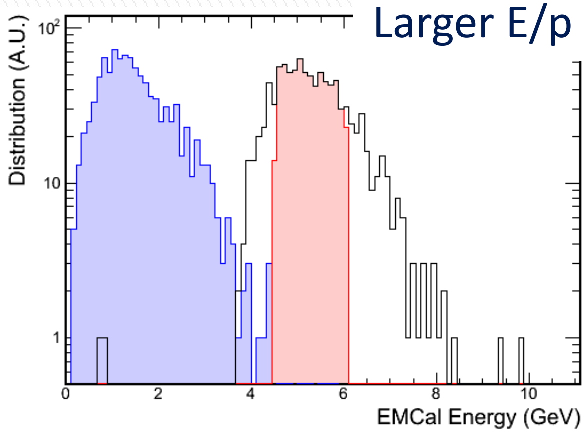
Fast group of Geant4 hit, need to re-evaluate in realistic towering!

Larger pseudo-rapidity in central AuAu : under study

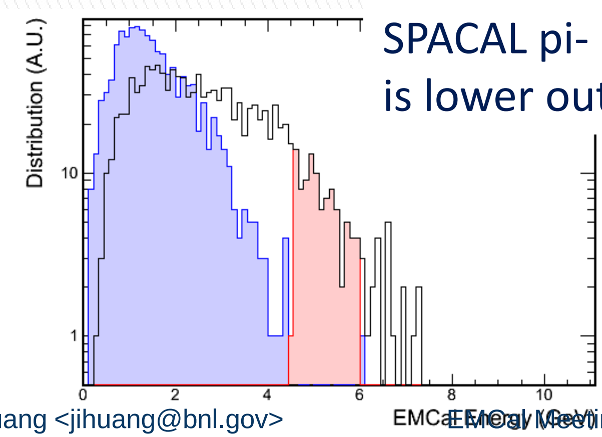
- Out of the box: larger |η| → larger background
  - Longer path length in calorimeter
  - Covers more non-projective towers
- to improve
  - **Better estimate of the underlying background event-by-event (improve x1.5)**
  - **Use (radially) thinner ECal (improve x2)**
  - **Possibilities for projective towers?**



- all events (w/ embedding)
- with EMCal E/p cut (w/ embedding)
- Hijing background (AuAu 10%C in B-field)

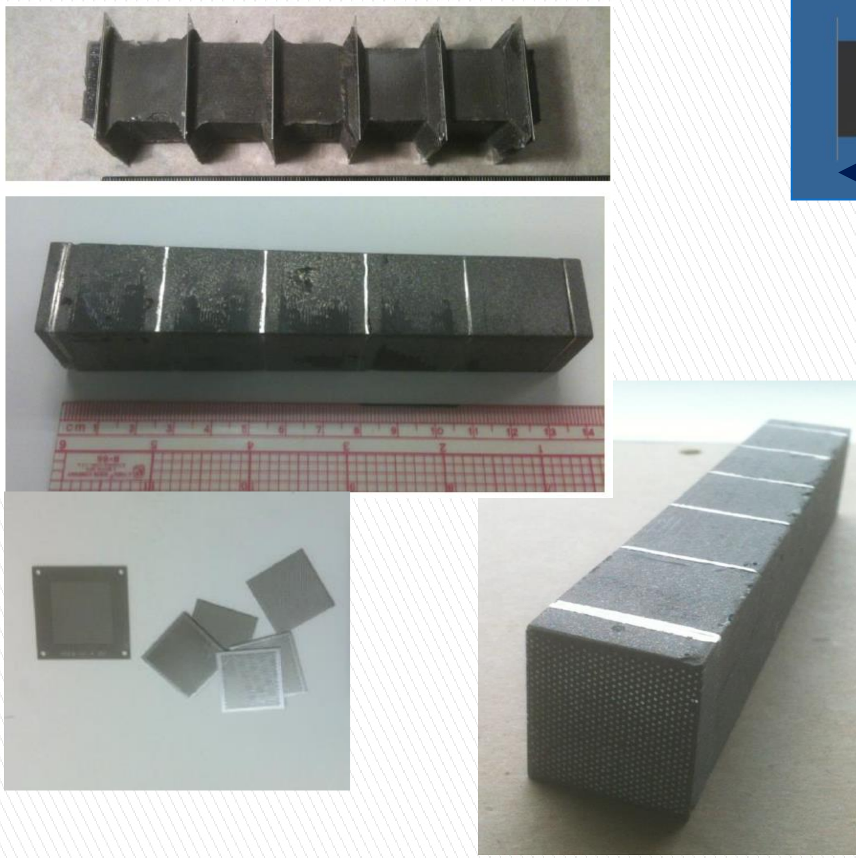


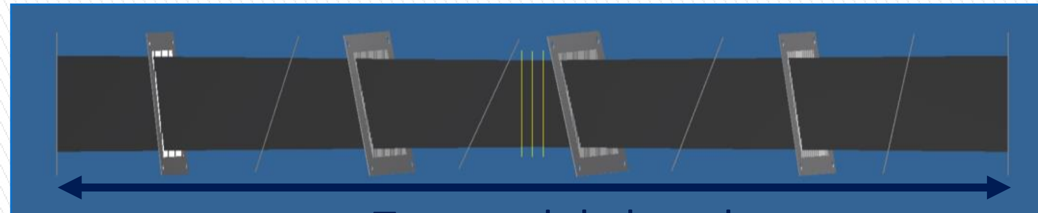
Out of box rejection ~10:1



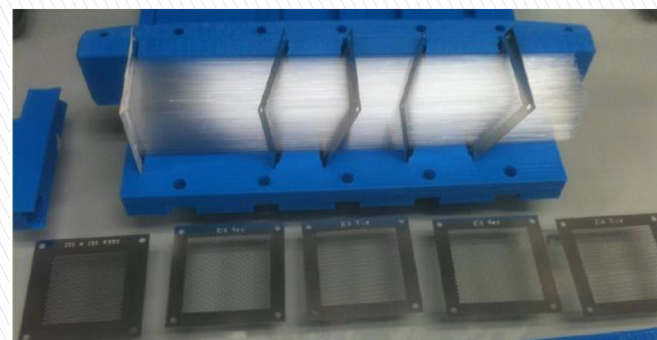
On-going R&D on 2D projective SPACAL

Sean Stoll (BNL), Spencer Locks (SBU), Jin Huang (BNL) and others





Two module length



R&D Direction 1:
Tapered step screens

R&D Direction 2:
Tilting Wireframes